

WEED MANAGEMENT

Growth and Fecundity of Several Weed Species in Corn and Soybean

S. A. Clay,* J. Kleinjan, D. E. Clay, F. Forcella, and W. Batchelor

ABSTRACT

Do weeds that emerge later in the season justify additional control costs? If crop yield is not reduced or few or no seeds are added to the soil seed bank, then no control may be needed. Eight weed species were sown in corn (*Zea mays* L.) and soybean [*Glycine max* (L.) Merr.] (i) before crop emergence, (ii) at crop emergence, (iii) at V-1, and (iv) at V-2 stages of crop growth in 2002 and 2003. Weed seed was sown close to the crop row and thinned to 1.3 plants m⁻². Weed growth and fecundity were influenced by species, time of planting, and year. Only barnyardgrass (*Echinochloa crus-galli* L.), redroot pigweed (*Amaranthus retroflexus* L.), and velvetleaf (*Abutilon theophrasti* L.) survived to produce seed. Plants from the pre-emergence seeding had the largest canopy and produced the most seeds. Barnyardgrass had maximum canopy cover in early July in corn and late July in soybean but only produced seed in corn. Redroot pigweed and velvetleaf had maximum canopy cover in late August or mid-September, and some plants from most seeding dates survived and produced seed in both corn and soybean. However, plants that grew from seed sown at V-1 and V-2 crop growth stages did not reduce yield or biomass of adjacent crop plants, had low fecundity, and may not warrant treatment. Control may be necessary, however, to prevent yield losses if weeds are present at high densities or to prevent establishment of uncommon species.

MANAGEMENT PLANS that do not contain herbicides with residual activity allow for weed emergence after the final scheduled treatment. The adoption of one or two pass herbicide programs that rely on glyphosate [*N*-(phosphonomethyl)glycine] provides no residual control for late-emerging plants. Weed flushes can occur throughout the growing season, depending on environmental and seed dormancy conditions (Clay and Scholes, 1992; Anderson, 1994; Grundy and Mead, 2000). These late-emerging weeds may reduce crop yields through competition, remain green to interfere with harvest, and/or produce high seed numbers that will increase soil seed bank reserves and future infestation problems.

Aggressive weed species, such as common waterhemp (*Amaranthus rudis* Sauer) and Palmer amaranth (*A. palmeri* S. Wats.), may warrant late-season control measures (Knezevic et al., 1994; Sellers et al., 2003). Common waterhemp can contribute several thousands of seed to the soil seed bank (Bensch et al., 2003) and

reduce crop yield (Hager et al., 2002). In addition, these weeds may be difficult to control in subsequent years due to the occurrence of herbicide resistance to many herbicide modes of action, including acetolactate synthase inhibitors (Hinz and Owen, 1997), protoporphyrinogen oxidase inhibitors (Shoup et al., 2003), photosynthetic inhibitors such as the triazines, and microtubule disruptor herbicides such as the dinitroanilines (Anonymous, 2004).

Late-emerging weeds, however, are less competitive with crops and have less biomass and fecundity than weeds that emerge before or at crop emergence (Knezevic et al., 1994; Dielman et al., 1995; Cowan et al., 1998; Bensch et al., 2003; Hartzler et al., 2004). If emerging weeds remain small, minimal impacts on crop yield and seed bank additions are expected. In these cases, control may not be needed. In fact, some biologists support leaving late-emerging weeds as a food source to benefit arthropod and bird productivity (Freckleton et al., 2004).

Limited data are available on the weed species and the timing of emergence that may result in minimal agronomic impact, i.e., few or no weed seeds produced and little or no crop yield loss. Plant fecundity and level of competition are influenced by weed species, crop (Van Delden et al., 2002), row spacing (Murphy et al., 1996; Mulugeta and Boerboom, 2000), time of emergence (Cardina et al., 1995), weed placement (in or between rows) (Donald and Johnson, 2003), and soil fertility (Van Delden et al., 2002). The objective of this study was to determine growth, fecundity, and yield loss potential of eight weed species common to the western region of the Midwestern United States Corn Belt sown into corn and soybean at four times during the growing season.

MATERIALS AND METHODS

Site Description and Plot Maintenance

The experiment was conducted in 2002 and 2003 at the Aurora Experiment Farm, Aurora, SD (44°19' N, 96°40' W). The plots were established on a Brandt silty clay loam soil (fine-silty, mixed, superactive, frigid Calcic Hapludoll) having 390 g kg⁻¹ sand, 383 g kg⁻¹ silt, and 226 g kg⁻¹ clay, a soil pH of 6.0, and organic matter content of 35 g kg⁻¹. Soil test results indicated that the N, P, and K content of the soil before fertilizer application was 9 kg N ha⁻¹ (0- to 60-cm depth) and 8 µg P kg⁻¹ and 133 µg K kg⁻¹ (0- to 15-cm depth) in 2002 and 32 kg N ha⁻¹, 6 µg P kg⁻¹, and 97 µg K kg⁻¹ in 2003. Before plot establishment each year, the field was chiseled in

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Abbreviations: GDD, growing degree days; PAR, photosynthetically active radiation.

the fall and field-cultivated in the spring. Urea and monoammonium phosphate (MAP) were broadcast-applied to both crops in the spring before planting at rates of 192 kg N ha⁻¹ and 42 kg P ha⁻¹.

The glyphosate-tolerant hybrid corn variety DK44-46RR was planted on 3 May 2002 and 7 May 2003 at a rate of 74 000 seed ha⁻¹ in 76-cm row spacing. Soybean (glyphosate-tolerant variety DeKalb 15-51RR) was planted at a rate of 445 000 seed ha⁻¹ on 17 May 2002 in rows spaced at 18 cm and on 21 May 2003 in 76-cm rows.

Treatments, Sampling, Experimental Design, and Data Analyses

Barnyardgrass, woolly cupgrass [*Eriochloa villosa* (Thunb.) Kunth], green foxtail [*Setaria viridis* (L.) Beauv.], yellow foxtail [*Setaria pumila* (Poir.) Roem. & Schult.], velvetleaf, common lambsquarters (*Chenopodium album* L.), redroot pigweed, and common ragweed (*Ambrosia artemisiifolia* L.) were sown in 2002. In 2003, barnyardgrass, velvetleaf, redroot pigweed, and common sunflower (*Helianthus annuus* L.) were sown. Seeds were obtained commercially and stored dry at about 2°C before planting.

An individual plot consisted of all weed species planted at a single planting time and had the dimensions of four rows wide by 12 m long in 2002 and four rows wide by 8 m long in 2003. The position of each weed species within each plot was randomized. About 20 to 30 weed seeds per species were planted about 1.5 cm deep, in the interrow area between Rows 2 and 3, 10 cm from the crop row at 1-m intervals at four crop growth stages: before crop emergence, at crop emergence, and at V-1 and V-2 stages of crop growth (Table 1). About 2 cm of water was applied to all plots if rainfall had not occurred within 4 d after planting to ensure adequate water for seed germination. After weed emergence, the area was thinned to one weed plant for a final plant population of 1.3 weeds m⁻². Any target weeds that emerged within the planted area after the first weed had emerged were removed, leaving the oldest weed in place.

Plots were maintained weed-free except for the species of interest using a combination of glyphosate application and hand weeding. A spot-spray application of glyphosate was used on 30 May 2002. Broadcast applications of glyphosate at 1.8 kg ha⁻¹ were applied with a bicycle sprayer on 5 June and 24 June 2002 and 6 June and 27 June 2003. Desired weeds were protected from the applications by covering with a plastic cup or bag immediately before treatment and removing after the treatment had dried.

Weed growth was monitored at 7- to 14-d intervals from emergence (mid- to late May) through mid-August and at harvest (late September). Weeds were measured for plant height at all sampling dates. Canopy area was determined by measuring the broadest part of the plant in two directions and

multiplying these dimensions. Canopy area was determined on 23 July, 1 and 19 August, and 26 September in 2002 and at all sampling dates in 2003.

Plant characteristics, such as number of seed capsules (velvetleaf), branches (redroot pigweed), or tillers (barnyardgrass), of weeds that survived and produced seed were recorded in 2003 at harvest. No evidence of seed loss (shattered capsules, partially shattered panicles, or spikes) was observed at harvest. The plant stem was clipped about 1 cm above the soil and placed into paper bags. The corn plant closest to and the three soybean plants adjacent to the weed were harvested for biomass in 2002 and grain yield in 2002 and 2003. Samples were placed in the dryer for 5 d at 32°C and biomass dry weight determined. Crop yield was determined for corn grain and soybean and reported in g plant⁻¹. The number of weed seeds per plant were determined after seeds were threshed and cleaned. Every year, about six random lots of 100 weed seeds each were counted and weighed. The total number of seeds per plant then was estimated from the seed weight.

The plots were replicated six times in 2002 and 10 times in 2003 using a randomized complete block design. Corn and soybean experiments were established in adjacent areas. Due to the differences in planting dates for the crops and weed seeds (Table 1) and differences in row spacing of soybean between years, each experiment was analyzed separately. In addition, control plots, where only the crop (in both years) or only the weed (planted at the same time as corn and soybean plantings in 2003) were planted, were established and replicated. Of the weeds that were planted, only barnyardgrass in corn and redroot pigweed and velvetleaf in corn and soybean produced seed in each year. Harvest data were analyzed by year in SAS (SAS Inst., 2000) using PROC GLM due to missing data because weeds were not present in all replications at harvest. Differences between means are reported at $P \leq 0.1$. This level of significance was chosen because weeds are not bred for uniformity nor homogeneity.

Total rainfall during the growing season was 35.5 cm in 2002 and 34.3 (corn) and 30.6 (soybean) cm in 2003. Differences in rainfall amounts in 2003 occurred because of the differences in planting date (Table 1). Rainfall was supplemented with irrigation, and the total applied water was 57.3 cm in corn and 53.5 cm in soybean in 2002. In 2003, total rain plus irrigation water applied to corn and soybean was 49.5 and 45.8 cm, respectively. The 30-yr (1971–2000) average rainfall total is 40 cm from May through September in Brookings. Weeds that developed from seed sown before crop emergence were exposed to 1415 growing degree days (GDD) in corn and 1308 GDD in soybean in 2002 and 1192 GDD in corn and 1148 GDD in soybean in 2003. The 30-yr GDD average from 1 May to 30 September is 1220. Detailed weather information is available at <http://climate.sdstate.edu/> (verified 13 Oct. 2004).

Table 1. Crop and weed planting dates and corresponding crop growth stages at Aurora, SD, in 2002 and 2003.

		2002				2003			
		Weed planting date	Emergence date			Weed planting date	Emergence date		
Crop	Crop growth stage		Barnyardgrass	Velvetleaf	Redroot pigweed		Barnyardgrass	Velvetleaf	Redroot pigweed
Corn (planted 3 May 2002) (planted 7 May 2003)	pre-emergence	15 May	29 May	29 May	29 May	7 May	18 May	15 May	23 May
	emergence	23 May	4 June	4 June	4 June	21 May	30 May	30 May	11 June
	first leaf stage (V-1)	29 May	11 June	4 June	11 June	27 May	6 June	6 June	11 June
	second leaf stage (V-2)	4 June	17 June	11 June	11 June	11 June	19 June	22 June	19 June
Soybean (planted 17 May 2002) (planted 21 May 2003)	pre-emergence	20 May	29 May	1 June	29 May	21 May	28 May	28 May	28 May
	emergence	29 May	4 June	4 June	6 June	30 May	6 June	6 June	6 June
	first unifoliate (V-1)	4 June	13 June	11 June	13 June	11 June	20 June	20 June	20 June
	first trifoliate (V-2)	11 June	19 June	19 June	19 June	19 June	25 June	25 June	25 June

RESULTS AND DISCUSSION

Plant Growth and Development

Seed germination was not tested before planting. However, seeds of each weed species were viable because at least one seedling emerged in each of the planted areas at each planting date. Common ragweed, common lambsquarters, and woolly cupgrass died a few days after germination regardless of date sown. Yellow and green foxtail in both crops survived from 2 to 8 wk but did not produce seed from any of the plantings. The cause(s) of the poor establishment and growth of these species is not known. Barnyardgrass in soybean grew and was present until harvest in each year but failed to produce seed, most likely due to competition stresses (light, water, and/or nutrient) imposed by the soybean. Based on 2002 results, barnyardgrass, velvetleaf, and redroot pigweed were planted in 2003. In addition, sunflower was included; however, an infestation of head-clipping weevil (*Haplorhynchites aeneus* Boheman) cut the stem just below the flower head in August, and plants failed to produce seed.

Seedling emergence from barnyardgrass, redroot pigweed, and velvetleaf seed sown pre-emergence to the crop (15 May for corn and 20 May for soybean) in 2002 occurred when the respective crop was in the V-1 growth stage, 29 May for both crops (Table 1). Plants from weed seed sown at V-2 stage of crop growth (4 June for corn and 11 June for soybean) emerged when the respective crop was in the V-3 growth stage. In 2003, weed seed sown pre-emergence to corn emerged from 6 d before corn emergence (velvetleaf) to 2 d after corn emergence (redroot pigweed) whereas all weeds in soybean emerged 2 d before soybean emergence (Table 1). Weeds emerged from the late-sown weed seeds at V-4 of corn and V-3 of soybean. Seedlings from seed sown in noncrop areas in 2003 emerged at the same time as seedlings in the crop.

The development of barnyardgrass, redroot pigweed, and velvetleaf differed among species, planting dates, and the type of crop interference (Fig. 1 and 2). Generally, plants that developed from seed sown before crop emergence had a larger canopy than plants that developed from seed sown at later dates. In 2003, it was evident that both corn and soybean greatly reduced the canopy area of each weed species when compared with plants grown without crop interference (Fig. 2 and 3).

The maximum canopy area of barnyardgrass in corn was 500 and 6000 cm² plant⁻¹ in 2002 and 2003, respectively, when seeds were sown pre-emergence to corn (Fig. 1a and 2a). Barnyardgrass in soybean had canopy areas of <300 cm² plant⁻¹ in 2002 for plants from the four planting dates (data not shown). In 2003, the largest plants in soybean were from seed sown pre-emergence that had an average canopy area of 1000 cm² plant⁻¹ (Fig. 2b). The differences between the canopies of barnyardgrass in soybean may have been due to the narrow- vs. wide-row soybean planting in 2002 and 2003, respectively. In contrast to the plants grown with each crop, barnyardgrass from seed sown before crop emergence and grown alone in 2003 had a maximum canopy area

of 12 000 cm² plant⁻¹ (Fig. 3a). Tillering accounted for the large canopy area of barnyardgrass, with individual plants having an average of 15 tillers plant⁻¹ in corn and up to 35 tillers plant⁻¹ when grown alone (data not shown). Barnyardgrass plants from seed sown at the V-1 and V-2 stages of corn produced an average of 2 tillers plant⁻¹ in corn and 5 tillers plant⁻¹ when grown alone.

Redroot pigweed plants from the pre-emergence seeding had the greatest canopy area when compared with other seeding dates (Fig. 1, 2c, 2d, and 3b). In 2002, plants grown in corn and soybean averaged about 1200 cm² plant⁻¹ from the pre-emergence planting and <200 cm² plant⁻¹ for plants from the V-2 planting (Fig. 1). In 2003, plants from seed sown at emergence had maximum canopy areas of 3000, 1000, and 5500 cm² plant⁻¹ for plants grown with corn, with soybean, and alone, respectively (Fig. 2c, 2d, and 3b). Redroot pigweed plants from later-sown seeds in the crops remained small, with canopies of <500 cm² plant⁻¹.

Velvetleaf plants in 2002 had the greatest canopy area when planted before crop emergence (Fig. 1). Maximum plant canopies ranged from two to six times less when seed was sown after the pre-emergence timing. Maximum velvetleaf canopy cover in corn was 1.5 times greater than the canopy produced in soybean. In 2003, the canopy areas of velvetleaf plants emerging from seeds sown pre-emergence to either corn or soybean were similar and averaged 3900 cm² plant⁻¹ (Fig. 2e and 2f). Velvetleaf plant canopies from V-1 or V-2 seedings were 2 to 20 times less than the canopies of plants from the pre-emergence seeding. Velvetleaf plants grown without crop interference (2003) had canopies two to four times larger than plants grown with crop interference (Fig. 2e, 2f, and 3c). The largest velvetleaf canopy area was observed in plants that developed from seed sown at crop emergence.

The canopy area of barnyardgrass from seed sown before corn emergence in 2003 was actually greater than the velvetleaf canopy area (Fig. 2a and 2e). Barnyardgrass produced many tillers that laterally spread into both row and interrow areas (data not shown). Velvetleaf had one main stem and remained upright, limiting the area covered.

Harvest Data

Corn yield averaged about 190 and 160 g plant⁻¹ in 2002 and 2003, respectively. Soybean yield averaged about 40 and 21 g plant⁻¹ in 2002 and 2003, respectively. The density of 1.3 plants m⁻² (1 plant m⁻¹ row) generally did not reduce crop biomass or height (2002) (data not shown). Yield was reduced most often by plants that developed from seed sown before crop emergence (Tables 2, 3, and 4). The density of 1 plant m⁻¹ row for redroot pigweed and velvetleaf has been reported to have minimal (<5%) impact on yield (Dielman et al., 1995; Scholes et al., 1995).

No barnyardgrass survived in soybean to produce seed in either year although row spacing differed between years. In contrast, 50% of barnyardgrass plants

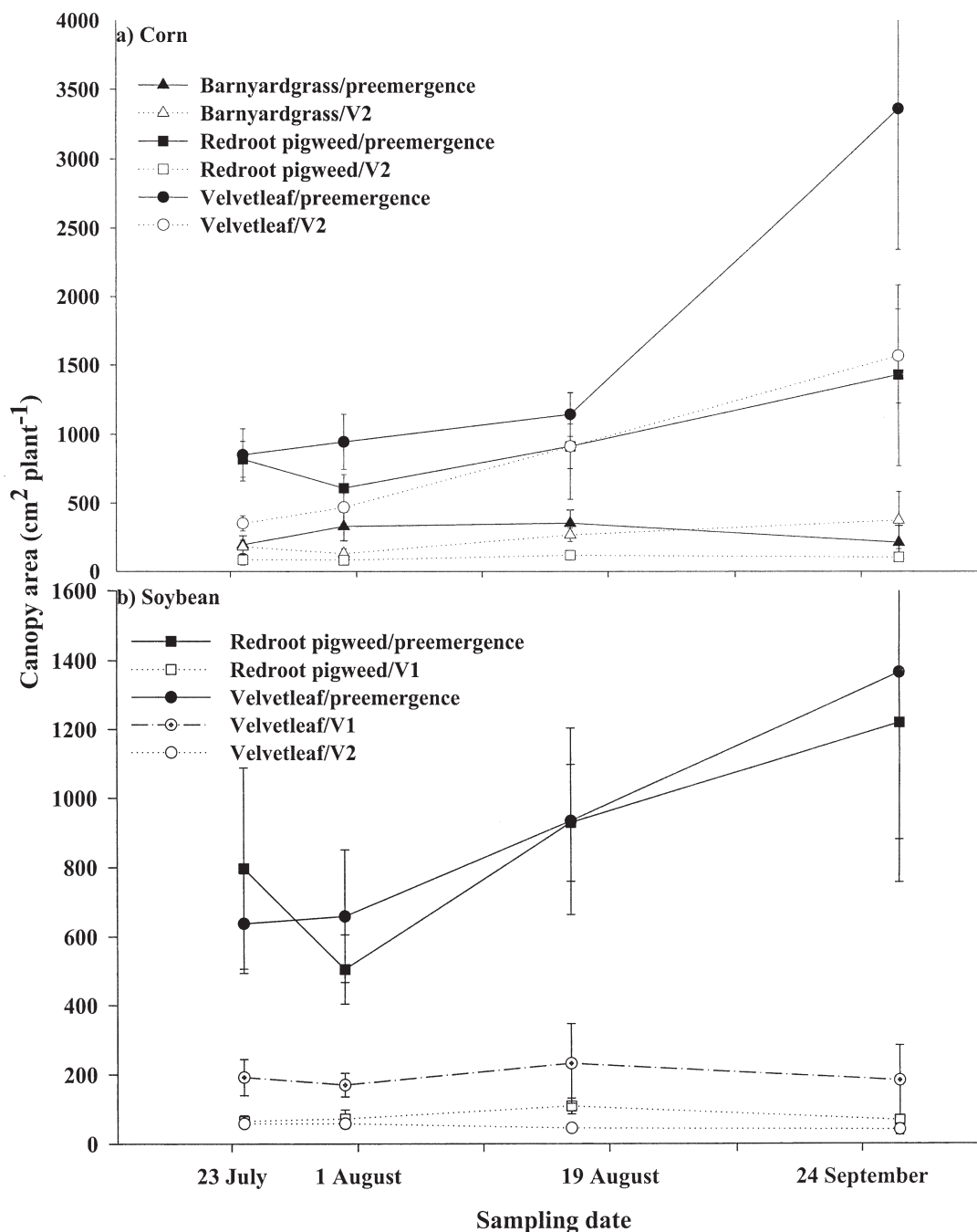


Fig. 1. (a) Weed canopy area of barnyardgrass, redroot pigweed, and velvetleaf planted pre-emergence and at the V2 stage of corn growth and (b) canopy area of redroot pigweed and velvetleaf planted pre-emergence and at the V1 and V2 stages of soybean growth during the 2002 growing season at Brookings, SD. Error bars indicate standard errors of the mean at $P = 0.10$.

from all planting times in corn survived and produced seed in 2002 (Table 2). There were no differences in barnyardgrass canopy area (Fig. 1), biomass, or fecundity among these plants. The average number of seeds produced was 380 seeds plant⁻¹. Corn grain yield was not influenced by barnyardgrass planting times. In 2003, about 85% of the barnyardgrass plants from seed sown from pre-emergence to V-1 and 30% of plants from seed sown at V-2 survived to produce seed (Table 2). Barnyardgrass plants from seed sown before corn emergence had greater canopy area, were taller, and reduced

corn yield 30% although the barnyardgrass biomass and seed number per plant were similar to plants from the other planting dates. Barnyardgrass fecundity when grown alone was 5 to 15 times greater than plants that developed from seed sown before or at crop emergence.

About 66 and 30% of the redroot pigweed plants in corn produced seed in 2002 and 2003, respectively (Table 3). Plants produced from seed sown before crop emergence in 2002 produced more seed than plants developing from seed sown at V-2 stage of crop growth in both crops. In 2003, plants from the earliest sowing

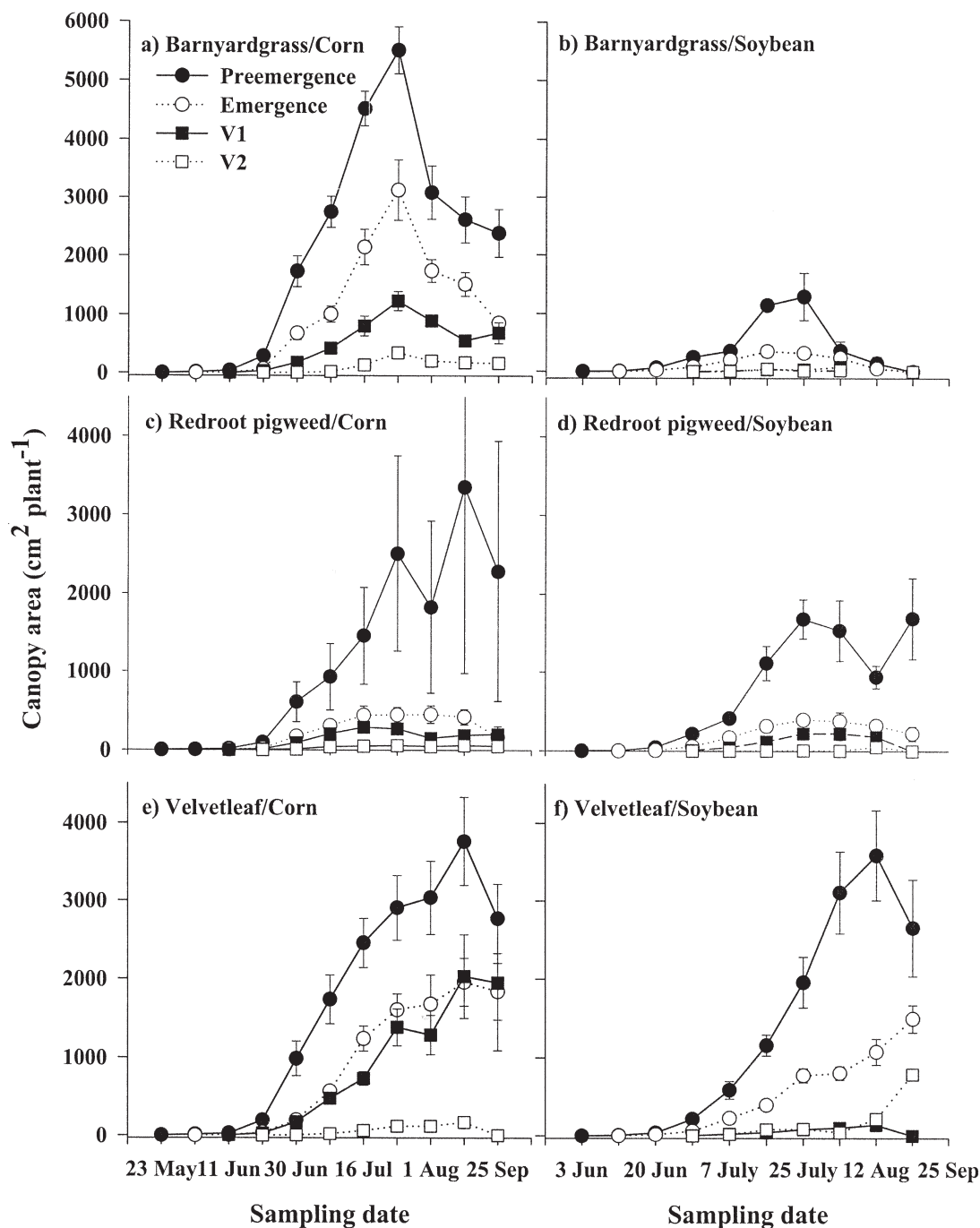


Fig. 2. Weed canopy area of barnyardgrass in (a) corn and (b) soybean, redroot pigweed in (c) corn and (d) soybean, and velvetleaf in (e) corn and (f) soybean at sampling dates during the 2003 growing season at Brookings, SD. Weed seeds were planted before crop emergence, at crop emergence, and at the V-1 and V-2 stages of crop growth, respectively. Barnyardgrass plants at all planting times in soybean failed to set seed, and plants were not present at harvest. Error bars indicate standard errors of the mean at $P = 0.10$.

produced many more seeds than the other plants, but due to high seed production variability among treatments, this value was not different than seed production of plants sown at other planting times. Redroot pigweed plants grown without interference generally had higher seed production than those grown in either crop. Corn yield across all planting times was similar to the weed-free control in 2002 whereas yield was reduced an average of 14% in 2003 regardless of planting date. Only

plants that developed from the earliest-planted seed reduced soybean yield in 2002.

Velvetleaf plants had higher survival rates in corn than soybean (Table 4). Seed capsule production in 2003 ranged from 0 on velvetleaf plants from seed sown at V-2 to 75 on plants from seed sown before crop emergence in both corn and soybean (data not shown). Similar numbers of velvetleaf seed were produced by plants from each planting time when compared across crops

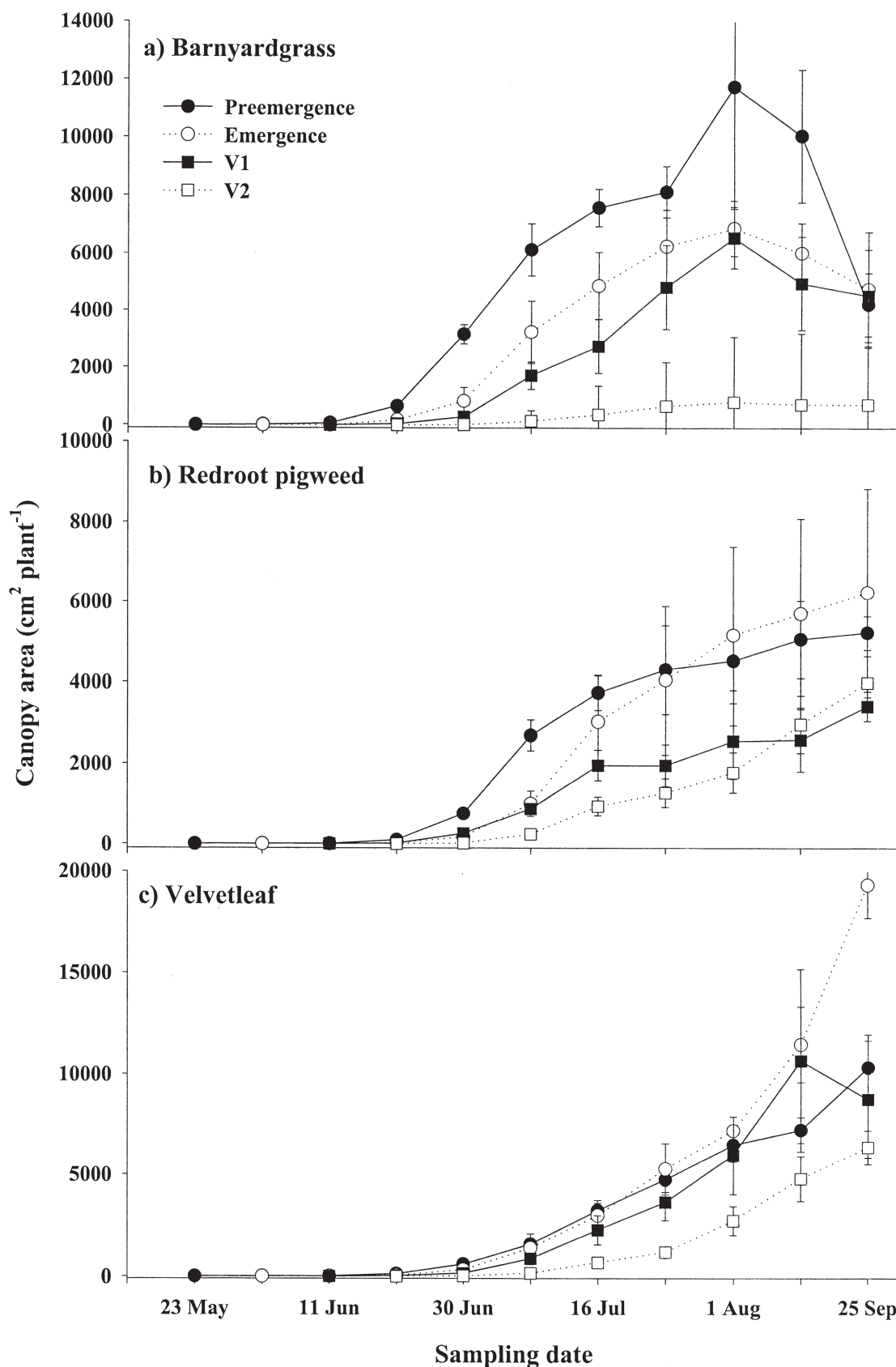


Fig. 3. Weed canopy area of (a) barnyardgrass, (b) redroot pigweed, and (c) velvetleaf grown without corn interference at sampling dates during the 2003 growing season at Brookings, SD. Weed seed was planted based on corn growth stages before emergence, at emergence, and at V-1 and V-2 stages of growth, respectively. Weeds planted in soybean at the same crop growth stages had similar canopy areas as those presented for corn (data not shown). Error bars indicate standard errors of the mean at $P = 0.10$.

Table 2. Barnyardgrass survival, height, biomass, and seed production and corn grain yield in 2002 and 2003 at Aurora, SD. Numbers followed by the same letter(s) within a year indicate no differences among treatments at $P \leq 0.1$.

		Barnyardgrass						Corn grain yield g plant ⁻¹
Treatment	Crop stage at weed seed planting	Survival	Height	Biomass	Seed per plant			
					Average	Minimum	Maximum	
2002		%	cm	g	no.			
With crop	pre-emergence	50	90 a	5 a	863 a	180	2 100	183 a
	emergence	50	63 a	4 a	199 a	143	250	176 a
	V-1	50	59 a	2 a	287 a	155	550	185 a
	V-2	50	51 a	7 a	157 a	45	340	176 a
	weed-free	—	—	—	—	—	—	194 a
2003								
With crop	pre-emergence	90	163 ab	33 b	3 385 b	1830	7 160	151 b
	emergence	80	103 cd	7 b	1 186 b	630	2 100	163 ab
	V-1	90	95 d	4 b	726 b	100	2 000	170 ab
	V-2	30	30 e	1 b	158 b	150	430	183 a
	weed-free	—	—	—	—	—	—	182 a
Without crop	pre-emergence	100	186 a	179 a	20 010 a	2710	51 000	—
	emergence	100	154 abc	161 a	15 250 a	900	32 100	—
	V-1	100	112 bc	50 b	5 175 b	4640	12 700	—
	V-2	100	106 c	37 b	6 460 b	1200	16 100	—

(Table 4). Velvetleaf seed numbers were larger for plants grown without crop interference. In 2002, velvetleaf interference reduced corn yield by 10% except where plants developed from seed sown at V-2 stage. In 2003, corn yield was reduced 9% by velvetleaf that developed from seed sown before crop emergence, at crop emergence, and at V-1. Soybean yield was reduced in both years only by velvetleaf plants that developed from seed sown before emergence. Yield reductions were 33% in 2002 and 47% in 2003.

Nitrogen fertilizer was applied to the soybean area, and all plots were irrigated. These conditions should have been optimal for both crop and weed growth, so that time of planting was the major influence of this study. Plants that emerged later in the crop cycle produced less seed than early emerged plants. Cardina et al. (1995) also reported large reductions (90% or greater) in velvetleaf seed production between early and late-emerging plants when grown with corn. The corn canopy

can reduce photosynthetically active radiation (PAR) penetration through the canopy by 40 and 60% at silking when planted at 7 and 10 plants m⁻², respectively (Murphy et al., 1996). The soybean canopy can reduce PAR penetration in the canopy from 50 to 100% at R-3 or later growth stages depending on cultivar characteristics (narrow vs. broad leaves), row spacing, and plant population (Flenet et al., 1996; Huggins et al., 1999). Growth from lower axillary buds of velvetleaf is inhibited by soybean interference (Regnier and Stoller, 1989). Bello et al. (1995) reported that 30 and 76% shading imposed 3 wk after velvetleaf emergence reduced velvetleaf seed yield from 22 to 93%, respectively, with corresponding reductions in growth parameters and seed capsules per plant compared with plants grown in full sun. These findings, in conjunction with data from this study, suggest that shading by the crop canopy is a major mechanism of interference to weed growth since N and water were similar between the two crops.

Table 3. The percentage survival, height, and seed production of redroot pigweed plants that survived to produce seed in corn and soybean in 2002 and 2003 at Aurora, SD. In 2002, redroot pigweed was grown only in the crop, whereas in 2003, redroot pigweed was planted in the crop and without crop interference. Numbers followed by the same letter within a crop and year indicate no differences between treatments at $P \leq 0.1$.

		2002						2003					
Crop	Crop stage at weed seed planting	Weed survival	Height	Weed seed per plant			Grain yield	Weed survival	Height	Weed seed per plant			Grain yield
		%	cm	Average	Min.	Max.	g/plant	%	cm	Average	Min.	Max.	g/plant
Corn	pre-emergence	66	107 a	6150 a	2720	14 970	198 a	40	118 a	4 680 b	64	16 600	142 b
	emergence	66	50 b	1300 b	640	3 053	168 a	20	80 abc	220 b	50	400	161 b
	V-1	33	36 b	1490 ab	40	2 930	186 a	30	30 cd	44 b	6	120	162 b
	V-2	83	34 b	118 b	36	210	198 a	30	16 d	25 b	9	55	161 b
	weed-free	-	-	-	-	-	194 a	-	-	-	-	-	182 a
	pre-emergence	-	-	-	-	-	-	80	71 bc	9 600 b	2 780	21 450	-
	emergence	-	-	-	-	-	-	80	69 bc	51 230 a	4 100	132 300	-
No corn	V-1	-	-	-	-	-	-	60	41 cd	5 120 b	1 200	21 400	-
	V-2	-	-	-	-	-	-	100	88 ab	16 500 b	4 400	32 400	-
	weed-free	-	-	-	-	-	-	-	-	-	-	-	-
Soybean	pre-emergence	100	101 a	5570 a	1270	11 200	27 b	70	100 a	9 870 cd	860	24 900	19 a
	emergence	16	73 b	3280 ab	-	-	43 a	50	80 bc	2 870 cd	60	7 500	17 a
	V-1	33	36 c	340 b	30	650	47 a	0§	0 d	0 d	-	-	-
	V-2	0	0 d	0 b	-	-	39 a	0	0 d	0 d	-	-	-
	weed-free	-	-	-	-	-	39 a	-	-	-	-	-	19 a
No soybean	pre-emergence	-	-	-	-	-	-	100	76 c	53 200 b	3 050	115 600	-
	emergence	-	-	-	-	-	-	100	98 ab	127 100 a	25 900	215 500	-
	V-1	-	-	-	-	-	-	100	102 a	53 400 b	30 150	94 800	-
	V-2	-	-	-	-	-	-	100	98 ab	30 700 bc	6 300	61 100	-

Table 4. The percentage survival, height, and seed production of velvetleaf plants that survived to produce seed in corn and soybean in 2002 and 2003 at Aurora, SD. In 2002, velvetleaf was grown only in the crop, whereas in 2003, velvetleaf was planted in the crop and without crop interference. Numbers followed by the same letter within a crop and year indicate no differences between treatments at $P \leq 0.1$.

Crop	Crop stage at weed seed planting	2002						2003					
		Weed survival	Height	Seed per plant			Grain yield	Weed survival	Height	Seed per plant			Grain yield
				Average	Min.	Max.				Average	Min.	Max.	
		%	cm	no.			g/plant	%	cm	no.			g/plant
Corn	pre-emergence	100	136 b	720 ab	200	2310	172 a	100	220 ab	2 200 cd	18	4 400	163 b
	emergence	50	188 a	1390 a	537	2460	140 b	90	192 bc	940 de	5	3 920	164 b
	V-1	83	154 ab	720 ab	73	1935	196 a	70	138 d	610 de	4	2 890	164 b
	V-2	100	104 b	230 b	70	540	186 a	0	0 e	0 e	—	—	180 a
	weed-free	—	—	—	—	—	191 a	—	—	—	—	—	182 a
No corn	pre-emergence	—	—	—	—	—	—	100	250 a	4 800 b	2600	6 670	—
	emergence	—	—	—	—	—	—	100	250 a	8 150 a	5160	14 000	—
	V-1	—	—	—	—	—	—	80	168 cd	3 170 bcd	420	7 520	—
	V-2	—	—	—	—	—	—	100	200 abc	4 120 bc	870	14 550	—
	weed-free	—	—	—	—	—	—	90	150 bc	2 030 bc	110	4 830	—
Soybean	pre-emergence	83	136 a	1225 a	260	2840	26 b	90	140 c	920 c	504	2 300	10 c
	emergence	33	160 a	1680 a	1421	1940	37 ab	90	140 c	920 c	504	2 300	17 a
	V-1	16	46 b	45 b	—	—	33 ab	10	27 d	0 c	—	—	12 bc
	V-2	16	5 c	0 b	—	—	28 ab	10	33 d	7 c	—	—	16 ab
	weed-free	—	—	—	—	—	39 a	—	—	—	—	—	19 a
No soybean	pre-emergence	—	—	—	—	—	—	100	170 a	9 660 a	110	16 400	—
	emergence	—	—	—	—	—	—	100	166 ab	11 760 a	7220	16 000	—
	V-1	—	—	—	—	—	—	100	165 ab	3 500 b	870	5 530	—
	V-2	—	—	—	—	—	—	100	157 abc	3 460 b	1840	6 810	—
	weed-free	—	—	—	—	—	—	—	—	—	—	—	—

Soybean interference at either row spacing generally reduced weed growth more than corn. Barnyardgrass plants did not produce seed in soybean, and redroot pigweed and velvetleaf plants that developed from seed sown at V-1 and V-2 produced no or very small amounts of seed. These three species at all planting times in corn survived and had greater fecundity than in soybean. However, the fecundity of these plants was low when plants emerged at or after the V-1 growth stage in either crop, and most likely, the seeds produced would have little impact on the soil seed bank. Nevertheless, control measures still may be needed. For example, if velvetleaf is not widespread in a field, just a few seeds from late-emerging plants may be cause for concern, whereas small additions of new seed from a more widely distributed species, like barnyardgrass, may not warrant control.

Further research should be conducted with higher weed densities to understand the balance between crop growth and the consequences of the late-emerging weeds. High densities of late-emerging plants may result in yield loss or lower fecundity of individual plants due to both intraplant and interplant competition for light, water, and nutrients. These changes may increase the return of seed to the seed bank due to more individuals producing seed in an area. In contrast, higher crop densities and more rapid and complete crop canopy coverage may counteract seed production of late-emerging weeds.

Whatever the case, the current results suggest that seed production from weeds that emerge late and escape control by nonresidual burn-down herbicides may be more of a problem in corn than soybean. Managers should recognize this difference between crops and plan control strategies accordingly; e.g., split glyphosate applications or soil-residual plus postemergence glyphosate in glyphosate-tolerant corn.

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